OP●AL ENC●

BACKGF

The present invention ǀ   and more

particularly to optical encoders   and linear

motions. The present invention   ʼtodiodes for

detecting light passing through a   ꞉ specifically

spaced from the raster.

Optical encoders function to register rotary angular motion or linear motion as well as direction of a moving body. Encoders generally comprise a light emitting system; a slit plate, raster or scattering arrangement, plate, sheet, or ruler (herein referred to as a raster); and a detecting arrangement positioned to receive light reflected off of or passing through the raster arrangement. The raster is attached to a rotating body, such as a shaft, for which the speed and direction are sought. The emitting system generally comprises a light emitting diode or laser diode with a lens arrangement optically coupled thereto. A light bundle may also be used to transport the light from the source to the raster arrangement. The detecting arrangement detects the light as modulated by the raster and generates information in response to the detection. The information is indicative of the speed and direction of the shaft to which the raster is connected.

In current encoders, the detecting arrangement is made or otherwise arranged to be evenly illuminated. Four photodiodes are typically employed and evaluation logic is electronically coupled to the detecting arrangement. The photodiodes are arranged linearly and parallel or tangential to the raster arrangement. The space between the photodiodes are one quarter of the raster arrangement period. The signals generated by adjacent photodiodes are phase shifted by ninety degrees respectively. The evaluation logic then determines the linear or angular speed of the raster arrangement based on the output of the photodiodes.

United States Patent 4,654,525 sets out an optical encoder arrangement for detecting rotational movement of a circular raster. The raster is concentrically arranged about a central axis and includes periodical openings moving between a light source and a linear array of four photodiodes. The photodiodes thus detect the

rotational motion of ⬤raster by analysis of light passing thr⬤n the raster openings and made incident upon the photodiodes. The opening within the raster is formed in such a way that the width of opaque or transparent areas corresponds to the combined lengths of two adjacent photodiodes and spacing therebetween. By this

5   arrangement, four adjacent signals are produced by the photodiodes, except that the signals are each out of phase by ninety degrees thereby producing an quadrature signal. The quadarture signals are fed passed adders and comparators so as to arrive at two quadrature signals out of phase by ninety degrees. The two signals are indicative of the rate and phase proportion of the rotary direction and speed of the

10 raster.

United States Patent 4,691,101 sets out a similar optical encoder. Herein several linear arrays of four photodiodes are successively arranged and the output of those diodes, in phase, are further electrically coupled. Alternative arrangement schemes are set out for arrangement of the photodiodes.

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BRIEF SUMMARY OF THE INVENTION

Heretofore, it is a given in the art that four semiconductor photodiodes are to be employed in an optical encoder. The area of each photodiode (along with some spacing) is set to half the area of the opening within the raster and further separately

20 electrically biased. As such, this arrangement entails high manufacturing and engineering costs as well as high consumption of semiconductor chip area.

Accordingly, it is an object of the present invention to set out an optical encoder for detection and analysis of linear or angular motions which can be produced at reduced engineering and manufacturing costs, be designed for high

25 replication, require reduced area of the semiconductor chip area, while still remaining relatively immune to light intensity fluctuations.

These and other objects of the present invention are accomplished by an optical encoder comprising: light emitting means for generating light; a raster for modulating said generated light, said raster comprising a plurality of periodically positioned first

30 and second formations, said first formations being opaque and said second formations being transparent, and said raster being attached to a moving element; light detection means for detecting light modulated by said raster, said light detection means comprising at least one set of three light detecting elements having light receiving areas being positioned in parallel to said raster, said elements generating

an output responsiv⬤ detected light; and evaluating mea⬤lectrically coupled to said detecting elements, said evaluating means comprising evaluating elements for receiving said detecting means output and generating an evaluating means output indicative of speed and direction of moving element.

5   The optical encoder according to the present invention includes three photodiodes. Herein, a reference signal is produced by a suitable evaluation circuit and used to compensate for light intensity fluctuations. The circuit includes an adder which receives the output of the first and third photodiodes. A signal level reduction component is connected to the output of the adder so as to produce a reference

10   signal at its output. The reference signal is then fed into at least two comparators which compare the reference signal with the output of the first and second photodiodes. The outputs of the comparators are quadrature signals which are indicative of the angular speed and direction of the raster. In addition, the signals are out of phase by ninety degrees. The signal level reduction means may be a divider,

15   lowering the adder output by a factor of two. Fluctuations of light intensity do not adversely effect the measuring capability of the present arrangement.

The present arrangement also employs sets of three photodetectors in place of the four used in the prior art. The photodetectors, which may comprise photodiodes, are spaced apart, such that the length of two light receiving areas of

20   two adjacent photodiodes is about the same as a length of an opaque or transparent formation in the raster. The combined length of the light receiving areas may correspond to half or three quarters of the period of the raster. Given the linear arrangement of the photodetectors, the compact space advantage of the prior art is preserved. Likewise, the at least one set of three photodetectors may be arranged

25   on a single substrate with the circuitry for the evaluation step formed thereon or therein. One advantage over the prior art lay in the reduction of at least one photodiode (from four to three), thereby resulting in decreased manufacturing and engineering costs. Additional advantages will become clear from the continued description of the present invention below.

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BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The novel features believed characteristic of the invention are set out in the claims below. The invention itself, however, as well as other features and

advantages thereof, ●e best understood by reference to ● detailed description, which follows, when read in conjunction with the accompanying drawings, wherein:

Figure 1 depicts a schematic representation of the present invention;

Figure 2 depicts an arrangement of an evaluation circuit;

5   Figure 3 depicts a graphical representation of the signal output of the instant three diodes; and

Figure 4 depicts a reference signal and two quadrature signals as produced by the evaluation circuit based on output from the three photodiodes.

10   ## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 depicts a schematic representation of the present invention. Herein a light bundle 10 coming from a light source (not shown) is depicted. The light source may comprise a light emitting diode, laser diode, vertical resonator light emission device such as a vertical cavity surface emitting laser (VCSEL), edge emitting

15   semiconductor laser, or other light generating means known to one skilled in the art. Where a VCSEL is used, an advantage of low emission divergence and high light density may be achieved. The output of the light source may be made parallel by an optically coupled lens prior to irradiance to the raster. As such, the light is made to evenly irradiate upon a raster 1, a raster disc or a raster ruler, positioned proximate

20   to the light source. The raster may be attached to a linear moving or rotating object or the like whose speed and direction are desired to be measured. The raster 1 comprises a periodic raster pattern made of transparent portions 11 and opaque portions 12. The portions are preferably about the same in length, the length running in the direction of motion of the raster. Preferably the portions having an equal size in

25   lateral direction.

The movement of the raster, direction indicated by arrow A, modulates the light from the light bundle as the light either passes through the transparent portions 11 or is blocked by the opaque portions 12. Positioned on the side of the raster opposite from the light bundle are three photodiodes: first photodiode 21, second

30   photodiode 22, and third photodiode 23. The present embodiment depicts a single set of three photodiodes. However, other embodiments may include more than one set of three photodiodes. The photodiodes are independently operated. Their light receiving areas may be arranged adjacently and in parallel to the raster. The combined length of the photodiode detecting areas spans three quarters of the period

of the raster. The combined length of two adjacent photodiode detecting areas spans the length of one portion (transparent or opaque) of the raster. As shown in figure 1, first and second photodiodes span the length of opaque portion 12. Third photodiode 23 lies entirely below transparent portion 11.

5   Skipping to figure 3, herein the output of the three photodetectors is depicted (40). The common ordinate 41 of the graphs relate to time while the abscissa 43, 45 and 47 relate to signal strength as related to the amount of incident light detected by the photodiode. First graph 42 relates to the output of first photodiode 21. Second graph 44 relates to the output of second photodiode 22. Third graph 46 relates to the

10   output of third photodiode 23. The graphs depict a typical scan where the raster is irradiated with evenly distributed light of an intensity relatively equal in strength as with respect to the three photodiodes. It is within the scope of the invention that other light strengths may be employed as well as appropriate elements in the evaluation means (to be discussed in more detail below) to compensate for the

15   same. As a transparent portion 11 moves across a raster thereby exposing more of the light detecting area of the photodiode to the light from the optical bundle, the rise in signal output power of each photodiode will be relatively the same. As such, each rise in power is depicted by a common rising graph segment 48. As the full area of the photodetector light receiving area is exposed to light, the output power of the

20   photodetector remains constant, as depicted by graph segment 50. As the light on the photodetector light receiving area falls due to the cutting off of light as effected by the on-coming opaque portion 12, the output power of the photodetector falls, consistently, as depicted by falling graph segment 52. A period of the raster is depicted on graph 40 by dashed lines 51, 53, 55, and 57. As shown, each

25   photodetector becomes fully exposed (50) at different successive times.

       The present invention takes advantage of the inverse power relationship between first and third photodetectors 21 and 23, graphs 42 and 46. This relationship is exploited to generate the reference signal which is relatively immune to light power fluctuations as will be detailed below.

30   Returning to figure 2, the figure depicts an embodiment of an evaluation circuit to be employed by the present invention. Equivalent elements and arrangements may be employed, as would be known by the skilled artisan, to accomplish the equivalent signal manipulation and output as will be set out below. Applying the arrangement depicted in figure 2, the output from the first and third photodetectors

are feed into an adder 31 which combines the two inputs into an output. The output represents about twice the maximum output of one of the photodetectors. The output of adder 31 is fed into divider 34 which divides the signal from the adder by two. The output of the divider serves as a reference signal as it remains relatively insensitive

5 to fluctuations in light intensity given the inverse relationship between the first and third photodetectors as depicted in figure 2. The reference signal is fed into a first and second comparator 32 and 33. The first comparator 32 is fed the output from the first photodetector 21 and outputs first quadrature signal QS1. Likewise, the second comparator is fed the output from second photodetector 22 and outputs second

10 quadrature signal QS2. The pulse rate of the two quadrature signals are indicative of the speed of the raster, while the phase of the two signals is indicative of the raster direction.

Figure 4 is a graphical representation of the two quadrature signals, QS1 and QS2, as well as the reference signal. In particular, the common ordinate of the

15 graphs 62 represents binary expressions of 0 and 1 (high or low) while the various abscissa 64, 66, and 68 of graphs 70, 72 and 74, indicate time. The period of the raster is again broken down by quarters, 61, 63, 65 and 67. The reference signal 69, as depicted in graph 70 remains constant given the inverse relationship of the first and third photodetectors. The first quadrature signal QS1 remains at low or 0 so long

20 as the output of the first photodiode 21 is smaller than the reference signal as determined by comparator 32. As soon as the output of the first photodetector 21 rises above the reference signal power level, the first quadrature signal QS1 rises to the binary level of 1 (high). QS1 rose to the binary level 1 (71) in the middle of the first quarter 61 and remained there until mid third quarter 65. Likewise, the second

25 quadrature signal QS2, rises to the binary level of 1 (high) when the output of the third photodetector is determined to be greater than the reference signal by second comparator 33. This occurred as shown in the middle of the second quarter 63 and lasted until mid fourth quarter 67.

The pulse rate of the first and second quadrature signals is indicative of the

30 linear or rotary motions of the raster, while the relative phase is indicative of the raster direction. Regarding phase and the present example, QS1 precedes QS2 (as depicted in figure 4) and therefore the raster is moving in the direction A as indicated in figure 1. Had QS2 preceded QS1, then the raster would have been moving in the opposite direction to A. QS1 and QS2 are ninety degrees out of phase. Had the light

intensity dropped by a factor of two, the reference signal as well as output signals of the first and third photodetectors all drop accordingly. As such, the comparators will still detect transition points of the photodetector outputs overtaking and falling below the reference signal at the same times. Therefore, the quadrature signals QS1 and

5   QS2 are independent of optical power fluctuations. Finally, the divider 34 may be replaced by other signal lowering means sufficient to lower the reference signal to a desired level whereby the outputs of the first and third photodetectors could exceed the reference signal level.

The invention being thus described, it will be obvious that the same may be

10   varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications would be obvious to one skilled in the art intended to be included within the scope of the following claims.